TIME DEPENDENT STUDY OF THE POSITIVE ION CURRENT IN THE ENVIRONMENTAL SCANNING ELECTRON MICROSCOPE (ESEM)

S.W.Morgan and M.R.Phillips

Microstructural Analysis Unit, University of Technology, Sydney, PO Box 123 Broadway, New South Wales, Australia, 2007

The Environmental Scanning Electron Microscope (ESEM) is capable of image generation in a gaseous environment at sample chamber pressures of up to 20 torr.[1] In an ESEM, low energy secondary electrons emitted from a sample surface, by virtue of the primary electron beam, are accelerated towards the positively biased metallic ring (typically +30 to +550V) Gaseous Secondary Electron Detector (GSED). As these electrons accelerate towards the ring they undergo ionizing collisions with gas molecules producing positive ions and additional electrons known as environmental secondary electrons. The environmental electrons further ionize the gas on their way to the ring producing a cascade amplification of the original signal. The amplified signal induced in the ring is used to form an image. The electric field generated between the GSED ring and the grounded stage causes the positive ions produced in the cascade to drift towards the sample, effectively neutralizing negative charge build up on the surface of a non-conducting sample.[2] It has recently been reported that a positive ion space charge exists in the region between the GSED and the stage.[3] The positive ion space charge develops because the mobility of an electron is approximately three orders of magnitude greater than that of a heavier positive ion.[4] The secondary electrons generated in the cascade amplification process are therefore swept towards the GSED and removed from the gas at a much faster rate than positive ions can recombine with electrons from the gas, sample, stage and or chamber. The contrast and overall signal gain in images obtained in the ESEM are essentially controlled by the distribution and recombination efficiency of positive ions in the sample chamber.[3,5]
The mechanisms of signal detection in the ESEM have been studied extensively for many years and several authors have presented work that experimentally and theoretically investigate the role of positive ions in the ESEM.[3, 5,6,7] However little is known about the time dependence of positive ion recombining processes and their effect on image formation. Time varying contrast in GSED images, due to positive ion transients, have been reported;[3] however there is a need to explore such phenomena at a quantitative level.

In this work the time dependence of the positive ion current is investigated as a function of various parameters such as GSED bias, sample type (conductor and insulator), gas pressure, gas type (Water vapour, Nitrogen and Argon) and stage geometry (conducting and insulating stage configurations). The variation of the positive ion current with time was studied using an earthed conducting probe connected to a sensitive electrometer and a digital data acquisition system. The probe was situated in the specimen chamber near the sample and its position relative to the stage, GSED and sample was kept constant throughout all experiments. For each time resolved positive ion current measurement the primary beam current was measured using a Faraday cup modified for use in the ESEM.[6,7] The electron beam was then positioned over the sample center, in spot mode, and the bias on the GSED ring, V_{GSED}, was set to zero volts. After the positive ion current reached steady state, at zero volts, V_{GSED} was then rapidly

Microsc. Microanal. 7 (Suppl 2: Proceedings)

set to a predetermined voltage between +30V and +550V. A small background signal induced in the probe by the primary beam before the onset of V_{GSED} was subtracted from the ion current versus time data set.

The time resolved ion current profiles show a general trend whereby the positive ion current rises rapidly to a maximum value and then decays to a steady state value (Figure 1). The decay of the positive ion current is attributed to the formation of a positive space charge between the GSED and stage. The time taken to reach the maximum ion current and steady state depends on the stage geometry (electric field distribution and ion recombination efficiency), V_{GSED} (cascade amplification) and gas type (ionization efficiency and cross-section).

References

1. G.D.Danalatos, *Adv.Elec.Electron Phys,*71(1988)109
2. D.A.Moncrieff et al., *J.Phys.D:Appl.Phys*, 11(1978)2315
. M.Toth and M.R.Phillips, *Scanning*, 22(2000)319
4. A.von Engel, *Ionized Gases, Clarendon Press, Oxford* (1965)
5. J.P.Craven et al., *Microscopy and Microanalysis(S2),* (2000)776
6. A.L.Fletcher et al., *J.Phys.D:Appl.Phys*, 30(1997)2249
7. P.Merideth et al., *Scanning*, 18(1996)467

Figure 1: Positive ion current versus time for Argon and Nitrogen gases in the ESEM at 3.0 torr pressure. (V_{GSED}=160V, sample = insulating, stage = insulating)